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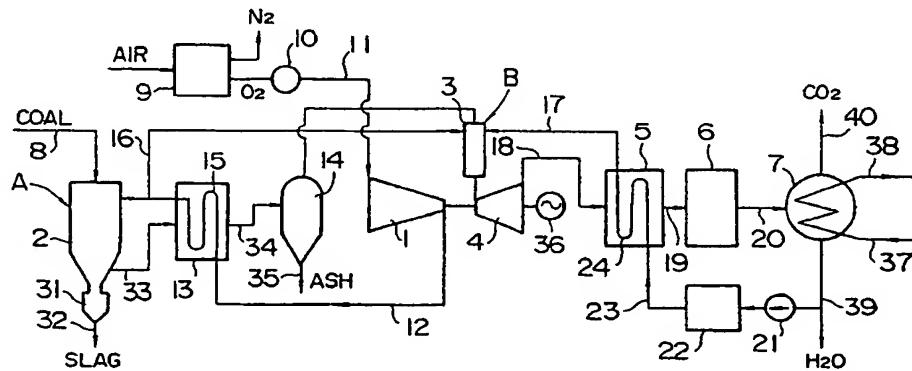
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(54) Power generation system.

(57) Under the purport of obviating the problems in the heat cycle, complicate system layout and separation of CO<sub>2</sub> in composite power generation system of prior art, the invention proposes a novel composite power generation system, which comprises a primary combustor for effecting a high temperature combustion of coal fuel under a reducing condition by compressed air or oxygen supplied from a compressor; a secondary combustor for effecting complete combustion of the resulting product gas of said primary combustor, said secondary combustor being supplied with said primary combustor product gas, air or oxygen for realizing said complete burning of the primary combustor product gas and an additive gas for controlling the combustion gas temperature in said secondary combustor consisting either of steam or of carbon dioxide; a gas turbine driven by a working fluid consisting of the resulting combustion gas of said secondary combustor and; disposed in series downstream of said gas turbine in the order, a waste heat steam generator, a desulfurizer and a condenser for the exhaust gas of the gas turbine.

## F I G. I



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## FIELD OF THE INVENTION AND RELATED ART STATEMENT

The present invention relates to a power generation system.

For better understanding of the stand of the technique, an explanation is first made for a typical coal gasification composite power generation system of the prior art with reference to Fig. 7 appended.

The gasifier unit is composed essentially of a primary combustor 01 and a succeedingly disposed reductor 07. The primary combustor 01 is supplied with coal and char as the fuel. By "char", it is meant a pulverous carbon deposited in the gasifier unit without being availed for the gasification. The primary combustor 01 is operated under a high temperature combustion of such supplied fuel under a reducing condition (an air ratio of less than 1) with compressed air. Coal is supplied to the primary combustor 01 from a coal supply duct 02. Char is recovered after the gasifier unit by a char collector 03 and returned to the primary combustor 02 via a char supply duct 04 as fuel supplement. A turbo compressor 05 is employed for supplying the compressed air to the combustor via an air duct 06. The combustion gas enters the reductor 07, where the intrinsic gasification of the coal fuel additionally supplied thereto from the supply duct 02 is realized according to the following reaction scheme:



The resulting product gas is cooled through a heat economizer 08 and is then passed to the char collector 03 via a gas duct 09 to recover the deposited char. The collected char is returned to the primary combustor 01 via the char supply duct 04 as explained previously.

The product gas leaving the char collector 03 enters then a dry desulfurizer 011 via a gas duct 010, where it is desulfurized. The desulfurized gas passes then through a dust remover 013 via a gas duct 012 to remove the entrained dust particles, before it is fed to a secondary combustor 015 constituting the burner for a gas turbine via a gas duct 014, where it is burnt completely by compressed air supplied from the turbo compressor 05. The resulting combustion gas drives the gas turbine 016 for generating an electric power by a generator 029 driven by the gas turbine. The gas turbine inlet temperature is controlled by adjusting the feed rate of the combustion air or, if the air feed rate is settled at a constant value, by adjusting the feed rate of coal to the gasifier unit.

The turbine exhaust gas is sent to a waste heat steam generator 018, where the sensible heat of the turbine exhaust gas is recovered by utilizing it for steam generation before it is discharged out to the atmosphere via a chimney 019.

The steam produced in the steam generator 018 is supplied via a steam main 020 to a steam turbine 021 for an additional power generation. The spent steam is condensed in a condenser 022 and the condensate is returned to the steam generator 018 and to the heat economizer 08 via each water feed line 024, 025 by a feed pump 023 under pressure elevation. The steam generated in the heat economizer 08 is also supplied to the steam main 020 via a steam line 026 and is availed for the power generation in the steam turbine 021. On combustion of the coal fuel in the gasification unit, molten slag of ash in a form of particles is formed, which fall down into a slag tank 026 and are discharged out to the outside of the system through a discharge duct 027. The dust collected in the dust remover 013 is taken out of the system via a discharge duct 028.

By the gas turbine 016, the generator 029 is driven to generate an electric power.

Coal gasification composite power generation systems of prior art as explained above have exhibited many problems left unsolved, such as follows:

## A) Problems in the Heat Cycle

The coal gasification is realized, as explained above, in the gasification unit composed of a primary combustor for producing a high temperature gas and of a reductor for gasifying the coal supplied thereto, in which the gasification is effected at a reaction temperature maintained at about 1,000 °C. Here, some time intervals are required for achieving sufficient mixing of the coal powder with the reaction gas and also for the gasification reaction to take place up to a sufficient degree, so that the gasification unit have to be designed in large scale. In addition, the wall of the gasification unit should be constructed as a water-wall similar to that of boiler furnace to reach sufficient cooling for protecting against the high temperature inside the unit.

For practical operation of dust removal and of desulfurization, the primary combustor product gas has to be cooled once to a low temperature, for example, to ordinary temperature, so that a waste heat recovery

means, such as, the heat economizer 08 or the like, should be installed at the outlet of the gasification unit, in order to recover the sensible heat of the product gas deprived upon the cooling thereof by generating a steam for driving a steam turbine power generator.

Thus, the coal gasification product gas which has been subjected to heat recovery by Rankine cycle is employed for the fuel of the gas turbine. In the above typical prior art system, the coal gasification product gas which has passed the heat economizer 08 is supplied to the burner 015 of the gas turbine 016. The exhaust gas of the gas turbine 016 is then once more subjected to a heat recovery by waste heat steam generator 018 for driving the steam turbine 021. Thus, the prior art system operates, from the stand of view of its heat cycle, in a sequence of a steam cycle/gas turbine cycle/steam cycle, namely a Rankine cycle (in the gasification unit)/a Brayton cycle (in the gas turbine)/a Rankine cycle (in the waste heat steam generator), that is to say, a system in which a steam turbine cycle is installed upstream the gas turbine cycle.

Therefore, the prior art system has to suffer from a lower over-all heat efficiency on the theoretical basis, as compared to a supposed system of simple combination of a gas turbine cycle with a steam turbine cycle, since an additional steam cycle (with a relatively low theoretical heat efficiency) is added preceding the supposed simple composite cycle of direct serial combination of a gas turbine cycle (with a relatively high theoretical heat efficiency) with a steam cycle. Explaining this with an exemplary calculation, the circumstance may be given as follows:

Supposing that the proportion of heat recovered in the gasification unit relative to the total enthalpy of the product gas to be, for example, 40 % and the gas having an enthalpy of remaining 60 % is supplied to the gas turbine operated with an over-all heat engine efficiency of, for example, 32 % and the over-all heat efficiency in the steam cycle of the gasification unit is, say, 40 % and that of the waste heat steam generator is, say, 20 %, the over-all heat efficiency  $\eta_1$  of the coal gasification composite power generation system of prior art is calculated by:

25

$$\begin{aligned}\eta_1 &= 0.4 \times 0.40 + 0.6 \times 0.32 + (0.6 - 0.19) \times 0.20 \\ &= 0.434 \\ 30 &= 43.4 \%\end{aligned}$$

In contrast thereto, the over-all heat efficiency  $\eta_2$  for the supposed simple composite cycle is calculated as:

35

$$\begin{aligned}\eta_2 &= 1.0 \times 0.32 + (1.0 - 0.32) \times 0.2 = 0.456 \\ &= 45.6\%\end{aligned}$$

40

Comparing the two calculations, it is seen that the over-all heat efficiency of the supposed simple composite cycle is higher than that of the coal gasification composite power generation system by a relative proportion of about 5 %.

Thus, it is recognized that an incorporation of a steam cycle preceding the combination of a gas turbine cycle with a steam turbine cycle causes a theoretical decrement of the over-all heat efficiency of the system.

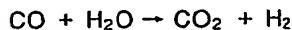
#### B) Problem in the Complexity of the System

The gasification unit operates at a high temperature of about  $1,000^{\circ}\text{C}$ . This high temperature brings about an inevitable large-sized design of the unit, in order to attain substantial completion of the conversion and, in addition, accompaniment of deposition of carbon, i.e. char, as described above. The deposited char should be returned to the gasification unit, necessitating thus means (such as 03 and 04) for collecting and returning the char. A heat recovering means, such as, the heat economizer 08, is also necessary for cooling the product gas from the gasification unit once to a low temperature, such as, to ordinary temperature. The necessity of such accessory installations brings about complexity of the system, in addition to the problem of the unavoidable large scale layout of the gasification unit, resulting thus in a large investment cost.

C) Problems incidental to CO<sub>2</sub> Removal

As to the removal of CO<sub>2</sub> from the waste gas for environmental protection, it is important, taking into account of the provisional or legal settlement of a limitation of the total amount of CO<sub>2</sub> permitted to be wasted into the atmosphere prospective in near future, to realize such removal or separation of CO<sub>2</sub> at the lowermost investment cost with minimum power consumption. In this respect, the previous coal gasification composite power generation systems have revealed problems such as follows:

- (1) An additional installation of an apparatus for removing or recovering CO<sub>2</sub>, such as, an adsorption column based on PSA or TSA, a low temperature cryoseparator and so on, is necessary.
- (2) An installation of a CO-shift converter for complete conversion of CO in the product gas from the coal gasification unit into CO<sub>2</sub>. The CO-shift converter for realizing the reaction



employs a conversion catalyst, which is subject to a deterioration of the catalytic activity after a certain operation period, requiring thus a frequent renewal of the spent catalyst.

(3) A large power consumption is required for the CO<sub>2</sub> separation in the prior system due to additional installation of a separate apparatus, such as, PSA, TSA or cryoseparator, therefor. These separation apparatuses require each a comparable energy consumption for separating CO<sub>2</sub>. Thus, an energy consumption of about 0.4 kWh (about 430 kcal) is necessary to separate 1 NTP m<sup>3</sup> of CO<sub>2</sub>. This value corresponds to about 10 % of the power generated by the system, which corresponds to about 20 % of the heat energy, bringing about a considerable energy cost for the CO<sub>2</sub> separation.

The world-wide stand of the technique today for the coal gasification composite power generation system proposed by various plant makers of the world is as explained above and, thus, there are many problems left still unsolved.

## OBJECT AND SUMMARY OF THE INVENTION

The object of the present invention is to provide a power generation system which is constructed so as to obviate the problems concerning the heat cycle, the complicate arrangement of the system and the technique for CO<sub>2</sub>-separation in the stand of technique explained above.

The above object is solved by providing a power generation system according to the present invention, which comprises a primary combustor for effecting a high temperature combustion of coal fuel under a reducing condition by compressed air or oxygen supplied from a compressor; a secondary combustor for effecting complete combustion of the resulting product gas of the primary combustor, said secondary combustor being supplied with said primary combustor product gas, air or oxygen for realizing said complete combustion of the primary combustor product gas and an additive gas for effecting control of the combustion gas temperatur in said secondary combustor consisting either of steam or of carbon dioxide; a gas turbine driven by a working fluid consisting of said secondary combustor combustion gas and; disposed in series downstream of said gas turbine in the order, a waste heat steam generator, a desulfurizer and a condenser for the exhaust gas of said gas turbine.

The primary combustor of the system according to the present invention serves for combustion of coal fuel under a reducing condition by the lowest necessary amount of compressed air or oxygen for effecting the combustion of the coal fuel at a temperature high enough to cause melting of ash from the combustion. This will bring about a high calorific value of the resulting product gas, a scarce rate of unburnt loss (below 1 %) of the fuel, a high separation rate (over 80 - 90 % or more) of the molten ash and an easy cleanup treatment of the product gas.

An employment of the lowest requisite amount of the oxygen-containing gas for the incomplete combustion in the primary combustor permits to form a product gas of the primary combustor having high calorific value to be supplied to the secondary combustor. Moreover, an installation of a steam cycle upstream the gas turbine is dispensed with. Therefore, it is able to obtain maximum amount of the combustion gas in the secondary combustor maintained at a scheduled gas temperature at the inlet of the gas turbine (the highest permissible temperature for the gas turbine), by controlling the amount of the oxygen-containing gas supplied to the secondary combustor. This is to say, that the maximum amount of combustion gas having the highest permissible temperature and having a calorific value corresponding to 100 % of the total enthalpy of the product gas supplied can be fed to the gas turbine, so long as the indispensable energy loss, such as, the heat dissipated into the environment etc., is neglected. Thus, it is possible to construct a coal gasification composite gas turbine power generation system of maximum

efficiency.

Moreover, an installation of the char recovery and recirculation means required in the prior art system can be dispensed with, since the composite power generation system according to the present invention does not form any char.

5 It is possible to design the heat exchanger for cooling the primary combustor product gas in smaller dimension, since it is enough to cool the product gas of the primary combustor only to a temperature lower than the melting point of the ash formed therein.

In the case of oxygen-burning (use of oxygen as the burning gas in the primary and secondary combustors of the system), the exhaust gas from the gas turbine is composed of only CO<sub>2</sub> and H<sub>2</sub>O (exactly speaking, scarce amounts of Ar and N<sub>2</sub> are included), so that CO<sub>2</sub> (having a small moisture content) can be separated from the steam content by simply cooling the exhaust gas of the gas turbine in a turbine exhaust gas condenser to cause condensation of steam into liquid phase water separated from the gas phase of CO<sub>2</sub>. Thus, an employment of installation of special means for separating CO<sub>2</sub> is unnecessary, with simultaneous omission of power consumption therefor.

15 In the air-burning (use of air as the burning gas in the primary and secondary combustors), the gas turbine exhaust gas is composed mainly of N<sub>2</sub>, CO<sub>2</sub> and steam (in the case of employment of water recirculation in the system explained below) or of N<sub>2</sub> and CO<sub>2</sub> (in the case of CO<sub>2</sub> recirculation in the system explained also below). Thus, the dry gas which has passed the exhaust gas condenser contains N<sub>2</sub> beside the content of CO<sub>2</sub>. However, the amount of dry gas is small due to the separation of steam content, 20 it is practically easy to realize separation of CO<sub>2</sub> from N<sub>2</sub>.

As described above, the system according to the present invention provides various advantageous effects as follows:

25 1) Each element for the gasification unit inclusive of the primary combustor can be designed in smaller size and the heat for cooling the primary combustor product gas is small, since the coal fuel for operating the system is supplied altogether to the primary combustor and the coal fuel is subjected to an incomplete burning at high temperature using the minimum requisite amount of compressed air or oxygen. The most part of ash formed in the gas produced in the primary combustor is removed within the gasification unit and the remainder part is removed in a subsequently disposed dust remover to a level permissible for the gas turbine. It is thus enough to cool the product gas of the primary combustor 30 only to a level below the melting point of the ash (usually above 800 °C) for carrying out the dry dust removal, allowing thus to design the heat exchanger for the product gas of the primary combustor in a small size with smaller heat required for cooling thereof. Therefore, the primary combustor and the heat exchanger for the product gas thereof may be designed in an air-cooled or oxygen-cooled construction, instead of a water-cooled construction. The resulting heated air or oxygen is utilized for burning the coal 35 fuel and for burning the product gas in the primary and secondary combustors.

In this manner, an improvement in the heat efficiency can be attained, since a steam cycle having a relatively low theoretical heat efficiency installed in a conventional coal gasification composite power generation system upstream the gas turbine can be avoided.

40 2) When the cooling of the primary combustor product gas is effected by heat exchange of the product gas with the oxygen-containing gas to be supplied to the primary combustor or using the steam generated in the waste heat steam generator, an employment of a steam cycle, which has lower theoretical heat efficiency, upstream the gas turbine can be omitted and, thus, an improvement in the heat efficiency is realized.

45 3) Due to the omission of the separate gasification part (reductor) in the gasification unit of the conventional system permitted by the employment of an integral gasification unit with total supply of the coal fuel altogether to the primary combustor and due to elimination of any char formation, a simplification of the gasification unit due to omission of reductor with its accessory members and of installations for the collection and recirculation of char can be attained.

50 4) In the case of oxygen-burning, the combustion gas in the secondary combustor consists substantially of CO<sub>2</sub> and H<sub>2</sub>O, so that CO<sub>2</sub> can be separated from the combustion gas by simply cooling and condensing the steam component as condensate in a condenser for the turbine exhaust gas, with elimination of requirement of power consumption for the CO<sub>2</sub> separation.

55 5) In the case of air-burning, the combustion gas in the secondary combustor consists essentially of N<sub>2</sub>, CO<sub>2</sub> and H<sub>2</sub>O with some minute gas components. Here, it is not able to attain separation of CO<sub>2</sub> simply by condensing the H<sub>2</sub>O content therein. However, the total amount of the combustion gas in the secondary combustor is relatively small (the air ratio requisite in the composite power generation system according to the present invention amounts only to about 1.1 as contrasted to that of about 3 in the conventional composite power generation system, producing thus only about 1/3 of the combustion gas

as compared with the conventional composite power generation system) and the temperature thereof is maintained relatively low, so that the separation of CO<sub>2</sub> is much easier than the conventional composite power generation system.

## 5 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic flow diagram showing an embodiment of the coal gasification composite power generation system employing oxygen-burning with water recirculation according to the present invention.

10 Fig. 2 is a schematic flow diagram showing an embodiment of the coal gasification composite power generation system employing oxygen-burning with CO<sub>2</sub> recirculation according to the present invention.

Fig. 3 is a schematic flow diagram showing an embodiment of the coal gasification composite power generation system employing air-burning with water recirculation according to the present invention.

15 Fig. 4 is a schematic flow diagram showing an embodiment of the coal gasification composite power generation system employing air-burning with CO<sub>2</sub> recirculation according to the present invention.

Fig. 5 is a schematic flow diagram showing another embodiment of the coal gasification composite power generation system employing oxygen-burning with water recirculation according to the present invention.

20 Fig. 6 is a schematic flow diagram showing a further embodiment of the coal gasification composite power generation system employing oxygen-burning with water recirculation according to the present invention.

Fig. 7 shows a typical embodiment of the coal gasification composite power generation system of prior art in a schematic flow diagram.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

25 Below, the present invention will be described in more detail with respect to six embodiments thereof with reference to each corresponding drawing.

The first embodiment of the present invention as illustrated in Fig. 1 employs oxygen-burning with recirculation of condensate as process water.

30 This composite power generation system comprises a gasification unit A including a primary combustor 2 in which a coal fuel supplied is subjected to a high temperature combustion under a reducing condition by supplying compressed oxygen from a turbo compressor 1; a combustion unit B including a secondary combustor 3 in which the product gas from the gasification unit A is subjected to complete combustion with oxygen under injection therein steam for effecting control of the combustion gas temperature; a gas turbine 4 driven by the combustion gas from the combustion unit B as the working fluid and; disposed in series 35 downstream said gas turbine in the order, a waste heat steam generator 5, a desulfurizer 6 and a condenser 7 for the turbine exhaust gas.

A pulverous coal fuel is supplied to the primary combustor 2 of the gasification unit A via a coal supply duct 8. On the other hand, oxygen (O<sub>2</sub>) isolated from air under separation of nitrogen in a cryoseparator 9 is 40 supplied to the primary combustor 2, under compression up to the scheduled pressure by a turbo compressor 1 (which is driven in this embodiment by the gas turbine 4) via an oxygen gas holder 10, a suction duct 11 and heat exchanger 13 for cooling the product gas of the gasification unit to a temperature permissible for the operation of a dust remover 14 operative to remove remaining dust particles entrained in the product gas.

45 The product gas from the primary combustor thus adjusted to a requisite temperature and separated from dust particles in the dust remover 14 is supplied to the secondary combustor 3 of the combustion unit B.

A part of the oxygen stream which has been heated in the heat exchanger pipe 15 is supplied to the primary combustor 2 in such an amount that the lowest minimum requisite amount of oxygen for burning 50 the coal fuel is supplied thereto. The remainder of the oxygen stream is passed to the secondary combustor 3 of the combustion unit B via an oxygen supply duct 16. The product gas of the primary combustor 2 is subjected to complete burning in the secondary combustor 3 by the heated oxygen supplied from the oxygen supply duct 16, whereby a high temperature combustion gas is produced. The temperature of this combustion gas is adjusted by injecting an adequate amount of steam supplied from a waste heat steam generator 5 via a steam main 17 so as to maintain the gas inlet temperature of the gas turbine at a scheduled value.

The gas turbine 4 is driven by the resulting temperature-adjusted combustion gas to generate an electric power in a steady state.

The exhaust gas from the gas turbine 4 is sent to the waste heat steam generator 5 via an exhaust duct 18 to effect a heat recovery there, whereupon the exhaust gas is passed to the desulfurizer 6 via a duct 19. Then, the so desulfurized exhaust gas enters the condenser 7 for the gas turbine exhaust via a duct 20, where a predominant proportion of the steam content is separated upon condensation by cooling as 5 condensate, a part of which is utilized under recirculation in the system.

The gas phase from the condenser 7 consists essentially of CO<sub>2</sub> having some moisture content. In this manner, separation of CO<sub>2</sub> can easily be attained without requiring any supply of external power with simultaneous recovery of water as condensate.

A part of condensate thus recovered is used for controlling the combustion gas temperature by injecting 10 it to the combustion unit. Thus, a partinent amount of the condensate to be used for maintaining the gas ourbine inlet temperature at a scheduled value is taken out and injected into the secondary combustor 3 of the combustion unit B under pressurization by a feed pump 21 after passing through a water treatment unit 22, a water supply line 23 and heat exchange pipe 24 in the heat exchanger 5. The condensate is heated upon passing through the heat exchanger pipe 24 and is converted into steam, which is supplied via the 15 steam main 17 to the secondary combustor 3.

Thus, there is no need for supplementing water from an external source in this embodiment.

In the embodiment shown in Fig. 1, other numerals denotes:

- 31 : A slag tank
- 32 : A slag discharge duct
- 20 33 : Exhaustion duct for the product gas of the primary combustor
- 34 : Dust remover inlet duct
- 35 : Dust remover discharge duct
- 36 : Generator
- 37 : Cooling water inlet conduit
- 25 38 : Cooling water outlet conduit
- 39 : Condensate extraction line
- 40 : CO<sub>2</sub> discharge line

The second embodiment of the composite power genration system according to the present invention is shown in Fig. 2, in which oxygen-burning and CO<sub>2</sub> recirculation are employed. The same or similar part of 30 the system as in Fig. 1 is represented by the same denotation symbol and the explanation therefor is omitted.

In this embodiment, CO<sub>2</sub> is separated in the condenser 7 for the gas turbine exhaust and is recirculated in the system under compression by the turbo compressor 1 driven by the gas turbine. It is returned to the secondary combustor 3 soas to adjust and maintain the temperature of the exhaust gas thereof to a 35 scheduled value.

The steam generated in the waste heat steam generator 5 is supplied to a steam turbine 41 via the steam main 17 to drive a generator 42. The exhaust from the steam turbine is condensed in a condenser 43 into condensate which is recirculated in the system by returning to the waste heat steam generator 5 by a feed pump 44 under pressurization via a supply line 45.

Oxygen to be supplied to the primary and secondary combustors 2 and 3 is separated from compressed air of a predetermined pressure supplied from an air compressor 52 driven by an electric motor 51 under the use of a cryoseparator 53.

Other numerals in Fig. 2 denote:

- 45 54 : Air intake duct
- 55 : Air exhaust duct
- 56 : Oxygen manifold
- 57 : Oxygen supply line

The third embodoment of the composite power generation system according to the present invention is shown in Fig. 3 in a schematic flow diagram, in which air-burning and water recirculation are incorporated. 50 The same or similar part of the system as in Fig. 1 is represented by the same denotation symbol and the explanation therefor is omitted.

In this embodiment, oxygen employed in the first embodiment shown in Fig. 1 is replaced by air. Installation of an air cryoseparator is thus dispensed with. The gas turbine exhaust gas here consists of N<sub>2</sub>, CO<sub>2</sub> and steam, so that the gas to be recirculated for controlling the temperature of combustion gas in the 55 combustion unit consists essentially of CO<sub>2</sub> and N<sub>2</sub> freed from the condensed steam.

The fourth embodoment of the composite power generation system according to the present invention is shown in Fig. 4 in a schematic flow diagram, in which air-burning and CO<sub>2</sub> recirculation are incorporated. The same or similar part of the system as in Fig. 1 or 2 is represented by the same denotation symbol and

the explanation therefor is omitted.

This embodiment corresponds to a system, in which oxygen employed in the second embodiment shown in Fig. 2 is replaced by air. Here, CO<sub>2</sub> is returned to the secondary combustor 3 under compression using an air compressor 52 driven by an electric motor 51.

5 The fifth embodiment of the composite power generation system according to the present invention is shown in Fig. 5 in a schematic flow diagram, in which oxygen-burning and H<sub>2</sub>O recirculation are incorporated. The same or similar part of the system as in Fig. 1 is represented by the same denotation symbol and the explanation therefor is omitted.

In this embodiment, the steam generated in the waste heat steam generator 5 is employed for the  
10 cooling medium of the heat exchanger 13 of the product gas of primary combustor in the first embodiment shown in Fig. 1. The oxygen from the turbo compressor 1 is supplied directly to the primary combustor 2 and to the secondary combustor 3 and the steam generated in the waste heat steam generator 5 is introduced into the secondary combustor 3 through a heat exchanger 13 for the product gas of primary combustor.

15 The sixth embodiment of the composite power generation system according to the present invention is shown in Fig. 6 in a schematic flow diagram, in which oxygen-burning and H<sub>2</sub>O recirculation are incorporated. The same or similar part of the system as in Fig. 1 is represented by the same denotation symbol and the explanation therefor is omitted.

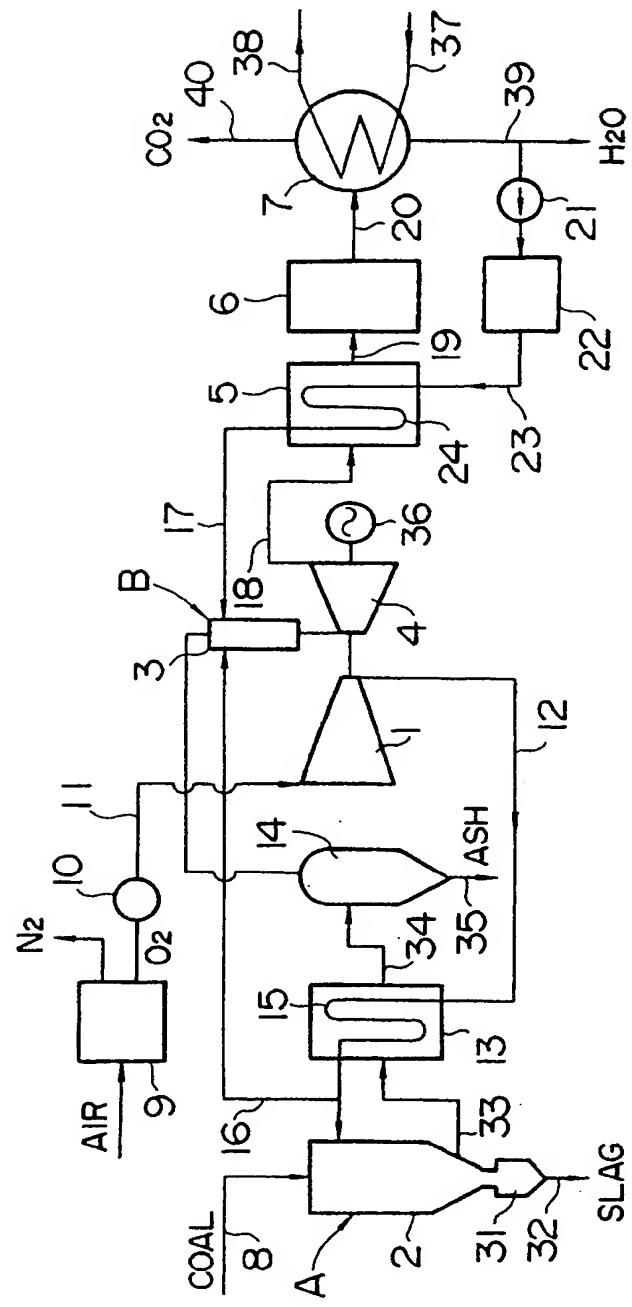
In this embodiment, a part of the steam generated in the waste heat steam generator 5 is employed for  
20 controlling the temperature of the product gas of primary combustor by spraying it within the product gas heat exchanger 13. The remainder of the steam is injected into the secondary combustor 3 for controlling the inlet temperature of the gas turbine.

Finally, it is to be noted, that employment of air in the place of oxygen in the embodiment shown in Fig.  
5 brings forth a further alternative of the composite power generation system in which air-burning and water  
25 recirculation are employed. When air is employed instead of oxygen in the embodiment shown in Fig. 6, another alternative of the composite power generation system is provided in which air-burning and water recirculation is employed, with steam spray cooling of the primary combustor product gas.

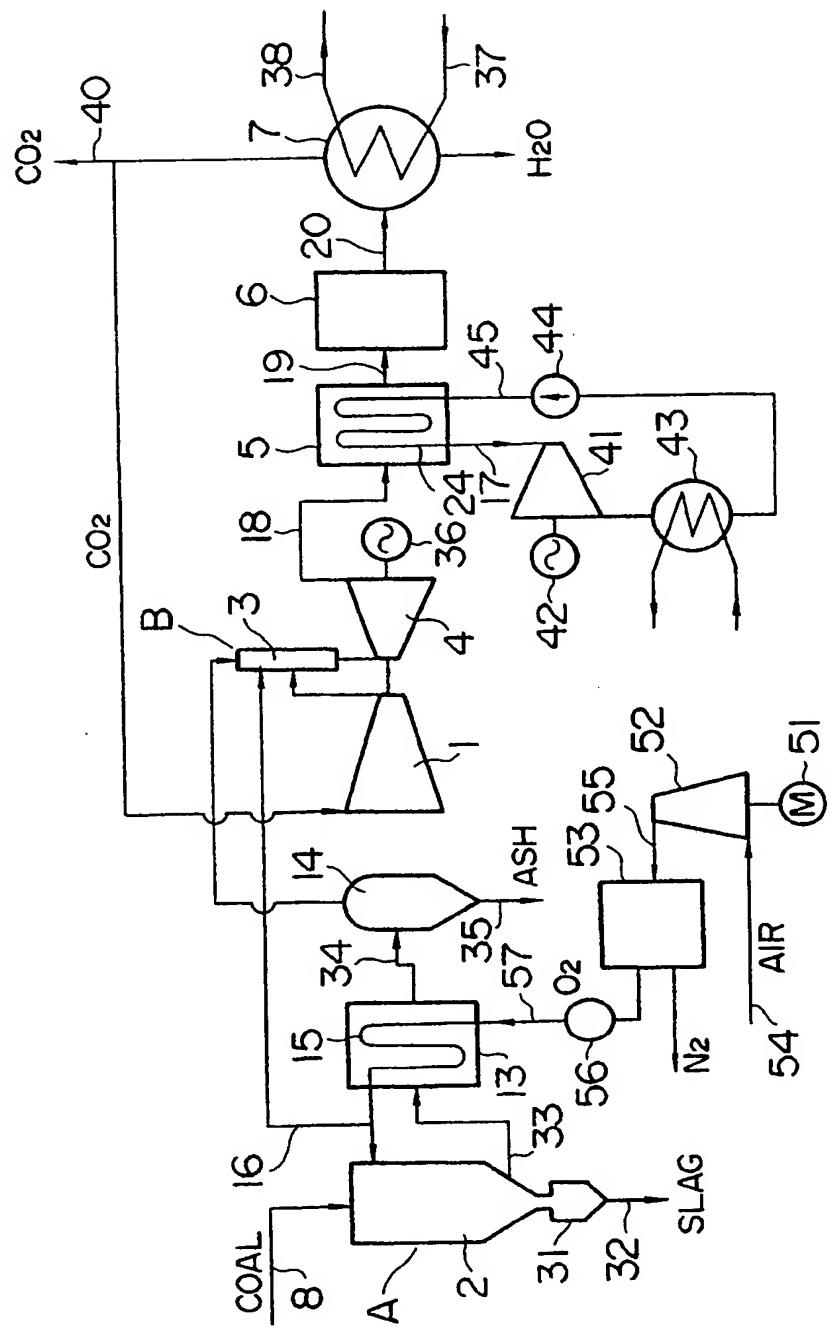
### Claims

- 30
1. A power generation system comprising a primary combustor for effecting a high temperature combustion of coal fuel under a reducing condition by compressed air or oxygen supplied from a compressor; a secondary combustor for effecting complete combustion of the product gas of said primary combustor, said secondary combustor being supplied with said primary combustor product gas, air or oxygen for realizing said complete combustion of the primary combustor product gas and an additive gas for controlling the temperature of the resulting combustion gas of said secondary combustor consisting either of steam or of carbon dioxide; a gas turbine driven by a working fluid consisting of said combustion gas from the secondary combustor and; disposed in series downstream of said gas turbine in the order, a waste heat steam generator, a desulfurizer and a condenser for the exhaust gas of the gas turbine.
  2. A power generation system according to Claim 1, wherein the steam supplied to the secondary combustor is generated in the waste heat steam generator.
  - 45 3. A power generation system according to Claim 1, wherein the carbon dioxide supplied to the secondary combustor is separated in the condenser for the gas turbine exhaust gas.
  4. A power generation system according to Claim 1, wherein a dust removal means is disposed in the product gas supply line from the primary combustor to the secondary combustor.
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F I G. 2



F | G. 3

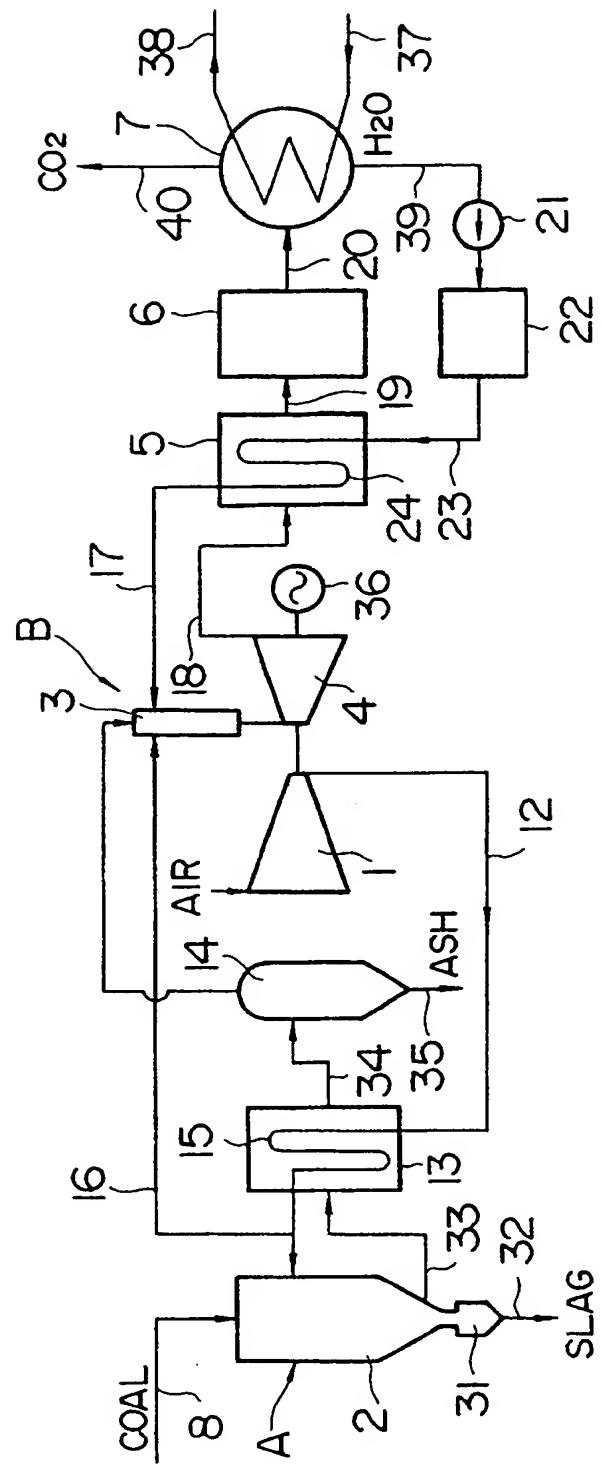


FIG. 4

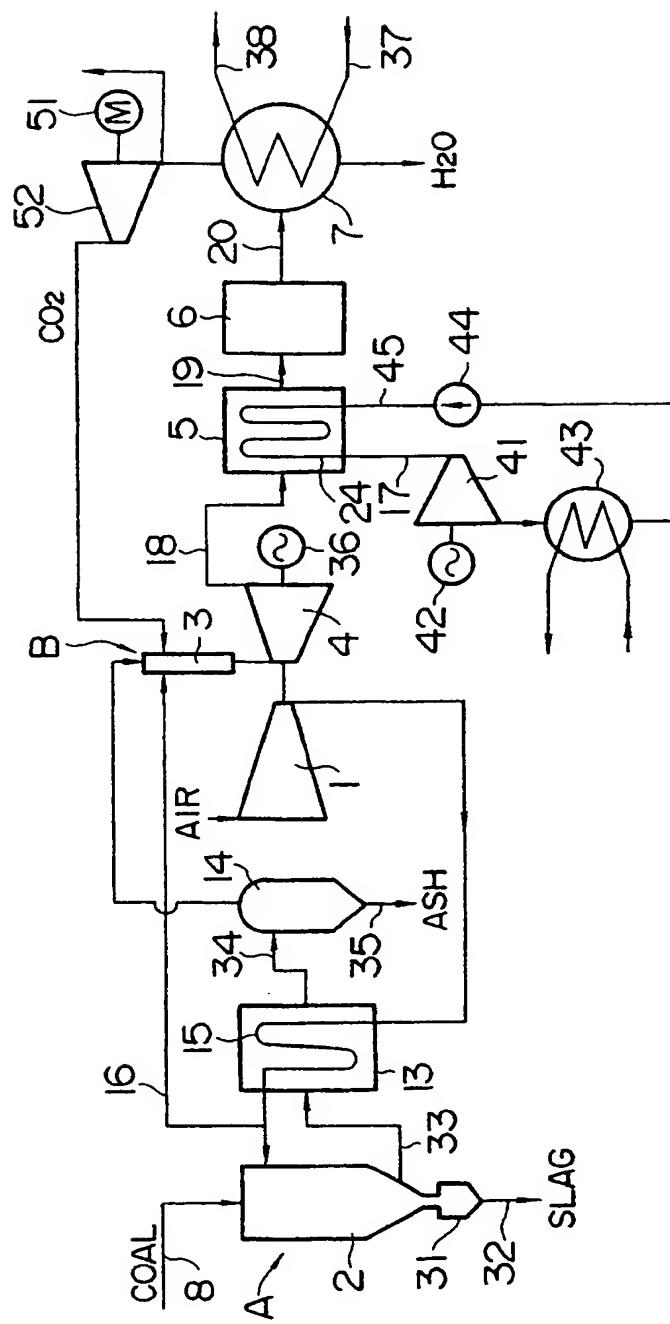


FIG. 5

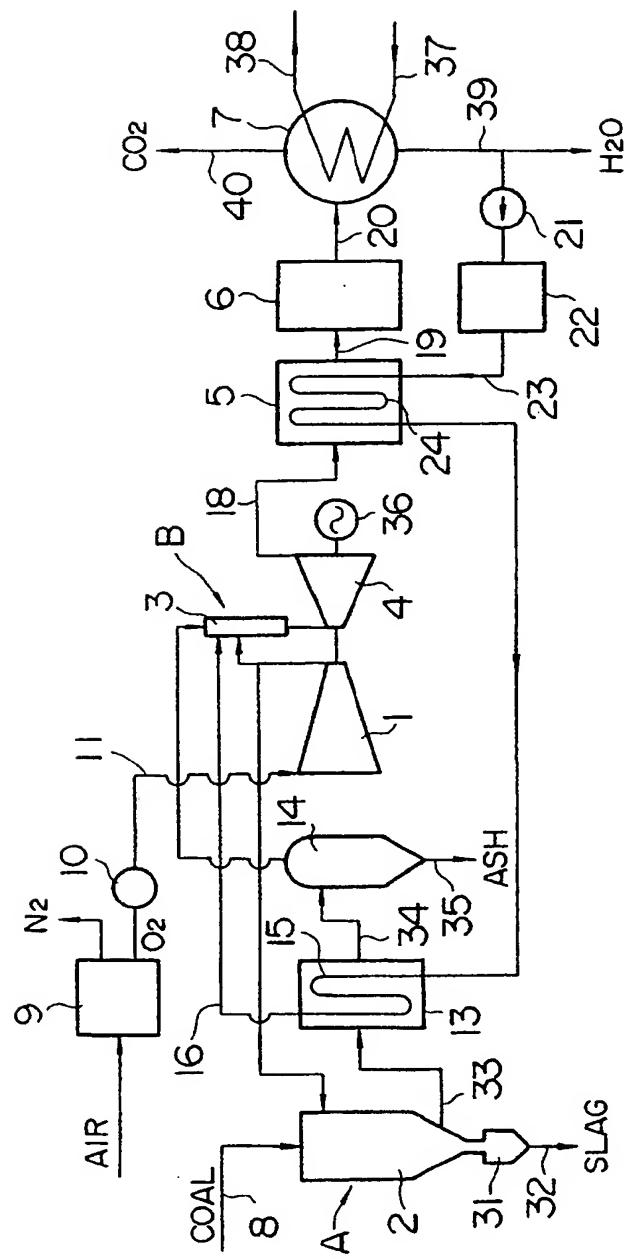


FIG. 6

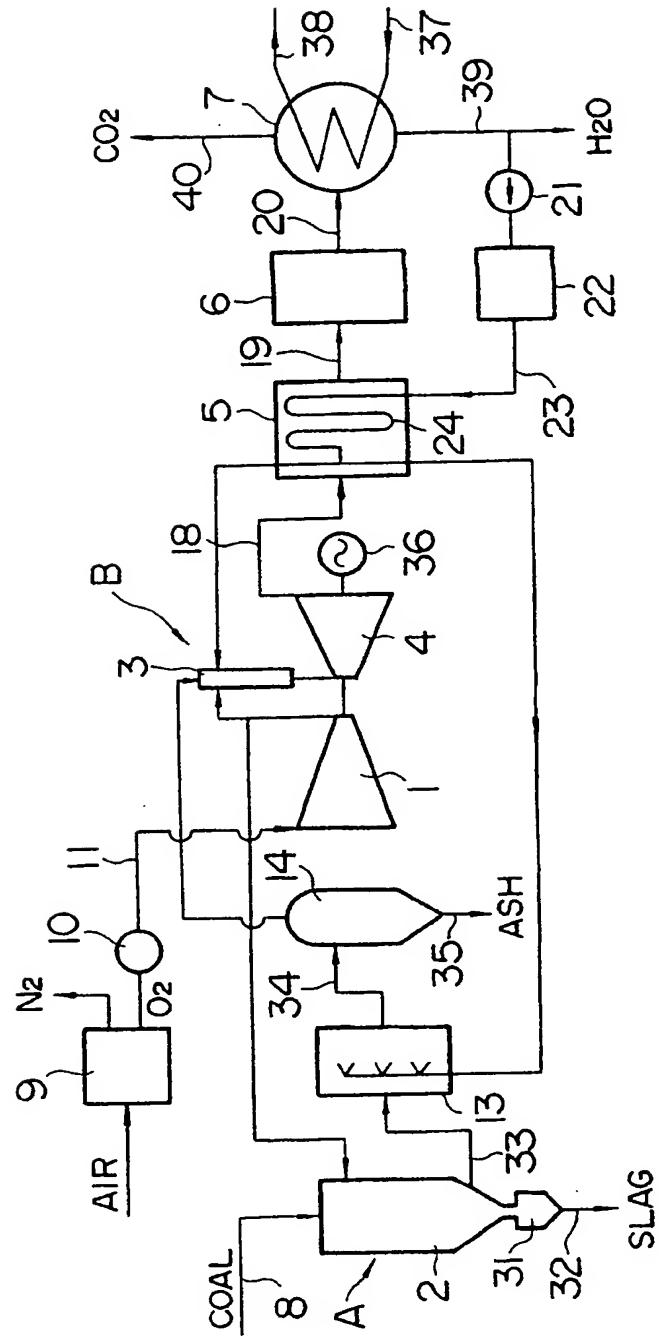
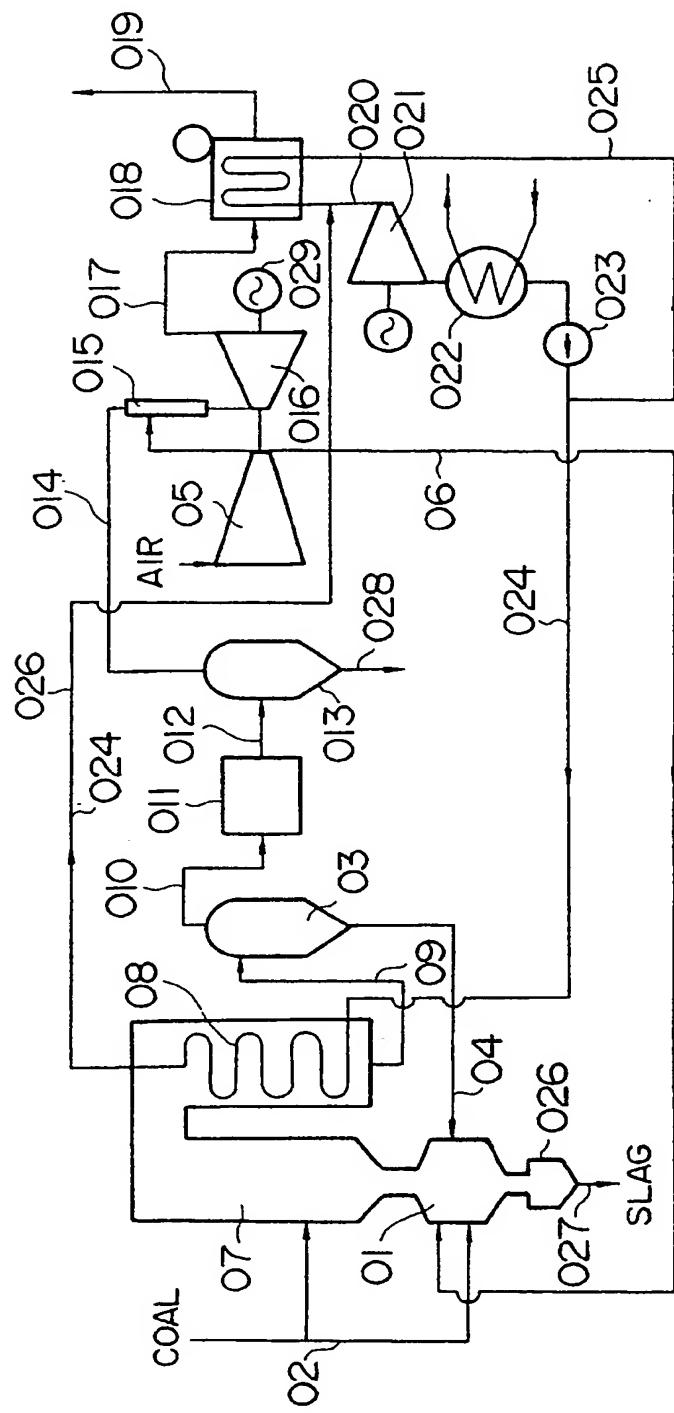


FIG. 7





European  
Patent Office

EUROPEAN SEARCH  
REPORT

Application Number

EP 91 25 0096

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	GB-A-1 104 075 (PRIKLADNOI MEKHANIKI SIBIRSKOGO OTDELENIJA AKADEMII NAUK) * the whole document * - - -	1,2,4	F 01 K 23/06 F 02 C 3/28
A	EP-A-0 184 137 (GENERAL ELECTRIC) * page 12, line 15 - page 16, line 30; figures * - - -	1,2	
A	GB-A-1 298 434 (KELMAR) * the whole document * - - -	1-4	
A	US-A-4 489 562 (SNYDER) - - -		
A	GB-A-2 191 215 (HUMPHREYS) - - - -		

TECHNICAL FIELDS  
SEARCHED (Int. Cl.5)

F 01 K  
F 02 C

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	05 August 91	VAN GHEEL J.U.M.
CATEGORY OF CITED DOCUMENTS		
X: particularly relevant if taken alone Y: particularly relevant if combined with another document of the same category A: technological background D: document cited in the application O: non-written disclosure P: intermediate document T: theory or principle underlying the invention	E: earlier patent document, but published on, or after the filing date L: document cited for other reasons &: member of the same patent family, corresponding document	